

# IN-FLIGHT MEASUREMENTS OF DYNAMIC FORCE AND COMPARISON WITH THE SPECIFICATIONS USED FOR LIMITING THE FORCES IN GROUND VIBRATION TESTS

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In-flight measurements of the dynamic forces acting between an aerospace component and its supporting structure have recently been obtained in two flight programs. During the past six years, a new vibration testing technique, in which the vibration force applied to the test item is limited to that predicted for flight, has been developed and used in many NASA space programs. (See T. Scharton, "Force Limits for Vibration Tests", *Spacecraft Structures and Mechanical Testing Conference*, Paris, June 1994.) Until recently there were no in-flight measurements of dynamic forces to evaluate the methods of predicting the force limits being used in these tests. Comparison of the in-flight data with the ground test data provides validation and small refinements of the methods currently being used for predicting the force limits.

The Advanced Composition Explorer (ACE) spacecraft was launched in August 1997 with eight scientific instruments to sample matter that comes near the Earth from the Sun. The spacecraft instrumentation includes a Spacecraft Launch Acceleration Measurement (SLAM) data acquisition system to measure, record, and transmit dynamic data at launch of the spacecraft on a Delta launch vehicle. The SLAM instrumentation includes a channel for the high frequency (20 to 2000 Hz) acceleration measured normal to the spacecraft honeycomb panel near one of the twelve mounting feet of the Cosmic Ray Isotope Spectrometer (CRIS) instrument and also a channel for the total normal force measured under the twelve mounting feet of the CRIS instrument. (The CRIS instrument is mounted on twelve uni-axial force transducers, and the output of these transducers is summed in real time.) Both the acceleration and force random vibration spectral density levels measured in flight for the CRIS instrument were approximately two orders of magnitude less than the corresponding values used in the CRIS ground vibration test program, so the instrument was severely overtested, even with force limiting. However, the ratio of the force frequency envelope to the acceleration envelope, which ratio is typically used to predict the force limits for ground vibration testing, was very similar in the in-flight and ground test data. Specifically, the in-flight data agrees with the previously published semi-empirical method of predicting force limits, when the proportionality constant  $C$  is chosen as two. (See K. Chang and T. Scharton, "Cassini Spacecraft and Instrument Force Limited Vibration Testing",

Third International Symposium on Environmental Testing for Space Programs, ESTEC, Noordwijk, June 1997.)

The Shuttle Vibration Forces (SVF) experiment measures the dynamic forces acting between the space shuttle and a Get-Away-Special (GAS) canister attached to the shuttle sidewall in two shuttle flights: STS-90 in April 1998 and STS-96 in December 1998. In previous shuttle flights, the acceleration at various positions in the shuttle cargo bay, including the sidewall input to GAS canisters, has been measured extensively. However, the SVF experiment provides the first measurements of the dynamic forces acting on shuttle equipment. The total dynamic forces acting on the GAS canister in three axes in the frequency range 5 to 2000 Hz are measured with piezoelectric force gages sandwiched between the shuttle sidewall and the GAS canister. The force data, as well as the data from two triaxial accelerometers in the canister, are captured by wide-band, battery-operated, digital recorders located inside the canister. The recorders are triggered automatically by the vibration associated with the start-up of the shuttle main engines. After the shuttle returns, the data are downloaded and analyzed with a PC. The in-flight data are compared with the force limits used in the ground tests of the GAS canister at NASA Goddard Space Flight center and the methods used to develop the force limits are evaluated and refined.

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